Insulation for Sustainable Cooling Systems

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AGENDA

- Need for Sustainable Cooling Systems
- Role of Insulation
- Types of Insulation
- Choosing the Right Insulation
- Technical Parameters
- Thickness Selection of Insulation
- Effect of External Surface Coefficient
The increasing population, technological advancements, and materialistic living standards have significantly increased the energy demand for cooling devices in last few decades.
Introduction

Need for Sustainable Air Conditioning

India has the least access to cooling systems which is reflected by its low per capita levels of energy consumption for space cooling at 69 KWh as compared to world average of 272 KWh.

- Growing Market for Cooling Systems.
- Means more Energy Consumption year on year on cooling systems
- All the more need to adopt sustainable cooling systems.
Need of renewable based technology

Sustainable Air Conditioning

The increasing use of fossil fuels not only causing fast depletion of energy sources but also causes emitting harmful gases which directly affects the human life.
INSULATION
INSULATION FOR SUSTAINABLE COOLING SYSTEMS

- Insulation – an integral part of all cooling systems.
- Responsible for Energy Efficiency in the cooling systems.
- Right Insulation would mean more efficient cooling systems.
- Insulation should be chosen to ensure energy savings for the life cycle of the insulation – stable thermal K values rather than the initial values and also eco friendly options should be chosen.
Insulation Materials

**inorganic**
- expanded perlite
- calcium silicate
- ceramic fibres
- mineral wool
- cellular glass
- silicate wool

**organic**

**manmade**
- elastomeric foam
- melamine foam
- polyethylene foam
- polystyrene
  - particle foam
  - extruded foam
- polyurethane
  - rigid foam
  - in-situ foam
- phenolic foam

**natural**
- cotton
- flax
- hemp
- coco fibres
- cork
- sheep’s wool
CHOICE OF THERMAL INSULATION

- Line Temperature
- Thermal conductivity ($\lambda$)
- Vapour barrier ($\mu$) (for cold work)
- Ease of installation (flexible insulation)
- Fire Classification
- Quality
- Neutral PH

Often Ignored by Designers
NBC 2016 recommends the use of Fibre Glass, PUF, EPS and **Flexible Elastomeric Foams** for Insulation of air-conditioning systems.

1. Ducting Insulation: as per NBC 2016 Part 8 - Building Services - HVAC Item No. 12.1.9.1

2. Chilled Water Piping: as per NBC 2016 Part 8 - Building Services - HVAC Item No. 12.1.9.5

3. Acoustic Insulation: as per NBC 2016 Part 8 - Building Services - HVAC Item No. 12.1.9.3

- Flexible Elastomeric Foams are Rubber Based Foams based on synthetic rubber.

- In the HVAC Industry, Nitrile Butadiene Rubber (commonly known as Nitrile Rubber) based foams are widely used.
THERMAL PROPERTIES OF INSULATION

Thermal conductivity $\lambda$ [W/(m·K)]

Example:

1. For Nitrile Rubber based FEFs at mean temp. 0°C

   $\lambda \leq 0.035$ W/(m·K)

2. For air $\lambda = 0.024$ W/(m·K)
SMALLER THE $\lambda$ - VALUE BETTER THE INSULATION

- copper: $\lambda = 380$ W/m·K
- wood: $\lambda = 0.20$ W/m·K
- foam glass: $\lambda = 0.045$ W/m·K
- mineral glass: $\lambda = 0.045$ W/m·K
- vacuum: $\lambda = 0.000$ W/m·K

$\lambda$ property of the material, is independent of insulation thickness.
THERMAL CONDUCTIVITY OF CLASS O ARMAFLEX IN RELATION TO THE MEAN TEMPERATURE

\[
\lambda = \frac{W}{m \cdot K}
\]

Mean Temperature
Deg Celsius

\(\nu_a = +22^\circ C\)
\(\nu_i = +6^\circ C\)
\(\nu_m = +14^\circ C\)
WATER VAPOUR TRANSMISSION / WATER VAPOUR PERMEABILITY
THE DRIVING FORCE BEHIND WATER VAPOUR DIFFUSION

\[ \nu_a = 22 \, ^\circ\text{C} \]
\[ \phi = 85 \% \]
\[ P_D = 22.5 \, \text{hPa} \]

\[ \nu_a = 6 \, ^\circ\text{C} \]
\[ \phi = 100\% \]
\[ P_D = 9.3 \, \text{hPa} \]
THE WATER VAPOUR DIFFUSION COEFFICIENT ‘δ’

- Generally known as Water Vapour Permeability

- “The amount of water vapour (Kg) which diffuses through a unit layer of material (of 1 meter thickness) and through a unit area (of 1 square meter), at a unit partial pressure difference (of 1 Pa), in unit time (of 1 hour)”

The lower the value, better is the insulation material
THE WATER VAPOUR DIFFUSION RESISTANCE FACTOR (µ)

“It is a dimensionless number describing how many times better a material is at resisting the diffusion of water vapour, compared with an equivalent thickness of air”

The Higher the value better is the insulation material
There is pressure difference of water vapour between ambient air and closed cell structure of insulation.

For poor quality material (low $\mu$ value) insulation will get wet.

Therefore one should apply high quality insulation materials i.e. with high value of water vapour diffusion resistance factor $\mu$. 

ambient temp. 22°C 
relative humidity RH 85%

temp. + 6°C 
RH 100%
Why is it Important to have High Vapour Water Diffusion Resistance Coefficient ($\mu$) in the Insulation Material?
WATER VAPOUR SHOULD NOT PENETRATE THE INSULATION SYSTEM FOR THE FOLLOWING REASONS

- In the insulation material they reduce the insulation effect considerably.

- Because water conducts heat around 20 times higher than static air
  \[\lambda(\text{air}) \approx 0.025 \text{ W/(m} \cdot \text{K)}; \lambda(\text{water}) \approx 0.6 \text{ W/(m} \cdot \text{K)}\]

- The thermal conductivity of ice is around 100 times higher than static air.

- This not only leads to higher energy losses, but in certain circumstances also means that the insulation thickness determined in the dry state is no longer sufficient. This in turn results in condensation formation on the surface of the insulation material.
WATER VAPOUR SHOULD NOT PENETRATE THE INSULATION SYSTEM FOR THE FOLLOWING REASONS

- Water can cause **corrosion** on insulated pipes and on the **inside of any metal jackets**. In the worst case this “creeping” corrosion can mean that the whole **refrigerating plant has to be replaced**.

- It is also important not to **underestimate** the **substantial weight gain due to water and ice**, which can lead to **static problems** – especially in combination with the corrosion processes.
EFFECT OF WATER VAPOUR PERMEABILITY

Examples of corroded pipe under a foil faced based insulation
EFFECT OF WATER VAPOR INGRESS ON THERMAL CONDUCTIVITY $\lambda$

Every 1% by volume increase in moisture of the insulation yields a 4 – 8% increase in thermal conductivity
μ-FACTOR OF TYPICAL INSULATION MATERIAL

NBR based FEFs

AIR  FG  PS  PUR  PEF  Glass foam  Glass

1  3~5  50~80  34~103  <1000  ≥ 7000  >130000  +∞
HIGH $\mu$-FACTOR – CLOSED CELL STRUCTURE OF FEFs

Armaflex insulation materials have a closed cell structure.
EFFECT OF HIGH $\mu$-FACTOR OF TYPICAL INSULATION MATERIAL

- Closed Cell Security
- Closed Cell Foam Protects Pipe from UIC
THE WATER VAPOUR DIFFUSION RESISTANCE FACTOR (µ)

“It affects long term behavior of insulation. Higher the ‘µ’ value better the long term efficiency insulation”

“NBC 2016 Part 8 – Building Services – HVAC Item No. 7.2.7.2.a

“Insulation Material Should not be Hygroscopic”

“NBC 2016 Part 11 – Approach to Sustainability - Item No. 9.2.4.1.1.c

“Closed cell flexible elastomeric foams naturally resist ingress of water vapour, help in long term efficiency of the insulation and minimizes chances of condensation and increased heat gain over a period of time”.
“The service life of the insulation depends primarily on the installed water vapour permeance of the system, comprised of the permeance of the insulation, vapour retarders on the insulation, and the sealing of the all joints, seams and penetrations….”
WHY VAPOUR BARRIERS ARE NOT ENOUGH?

• They are susceptible to damage during installation.

• Some foils which are used as a Vapour Barrier, are known as good vapor barriers, may have small pin holes which does not serve its purpose.

• In practical site conditions, it is very difficult to install vapour barriers properly.
CONDUCTIVITY IS A FUNCTION OF ‘μ’

‘μ’ and Thermal Conductivity ‘λ’ both are important

When specifying or purchasing insulation for cold systems, remember that Thermal conductivity and WVT are both important to the long-term integrity of your system.
Heat flow and diffusion flow are caused by the difference in the line and ambient temperatures.
FIRE PERFORMANCE
“NBC 2016 Part 4 – Fire & Life Safety Item No. 2.7
“Combustible material is a material which either burns itself or adds heat to Fire”

“NBC 2016 Part 8 – Building Services - HVAC Item No. 7.2.7.2.a
“Insulation Material shall be non-combustible”

“NBC 2016 Part 8 – Building Services - HVAC Item No. 7.2.7.2.a
“Insulation Material shall not produce noxious smoke and toxic fumes”
FIRE PERFORMANCE OF NBR - FLEXIBLE FOAM INSULATION

BS 476 Part 4 – Non-Combustibility Test

BS 476 Part 7 – Test for Surface Spread of Flames – Rated as Class ‘1’

<table>
<thead>
<tr>
<th>Class</th>
<th>Flame Spread Distance (1.5 min)</th>
<th>Flame Spread Distance (10 min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1</td>
<td>165mm</td>
<td>165mm</td>
</tr>
<tr>
<td>Class 2</td>
<td>215mm</td>
<td>455mm</td>
</tr>
<tr>
<td>Class 3</td>
<td>265mm</td>
<td>710mm</td>
</tr>
<tr>
<td>Class 4</td>
<td>Exceeding the limits for Class 3</td>
<td></td>
</tr>
</tbody>
</table>

BS 476 Part 6 – Test for Fire Propagation – **Rated as Class ‘0’**. (Class 1 is must to perform this test). Result in the form of Initial Index $\leq 6$ and Total Index $\leq 12$. 
FIRE PERFORMANCE OF ARMAFLEX INSULATION

UL 94 – Fire Test for Horizontal Burning and Vertical Burning.

BS 6853:1999 – Tested for Smoke Toxicity – R Value = 0.54

FM Approved – Factory Mutuals, U.S.A.

HEALTH HAZARD IN RELATION TO INSULATION MATERIAL USED

“NBC 2016 Part 8 – Building Services – HVAC Item No. 7.2.7.2.c

“Material should not cause a known hazard to health during application, while in use or on removal, either from particulate matter or from toxic fumes”

Flexible Elastomeric Nitrile Rubber Foams are closed cell non-fibrous materials and do not cause any health hazard. They are dust free and fiber free. Non-Carcinogen.

No risk of erosion – Tested for Air Erosion Test for 10,000 fpm Air velocities as per ASTM C – 1071-05 for FEFs used as Duct Liner
ANTIMICROBIAL AND ANTIFUNGAL BEHAVIOUR
ANTIMICROBIAL & ANTIFUNGAL PROPERTIES OF INSULATION MATERIAL USED

“NBC 2016 Part 8 – Building Services – HVAC Item No. 7.2.7.2.a

“Insulation Materials and their finishes should inherently prohibit rotting, mould and fungal growth, attack by vermin.

NBR based FEFS do have products with in-built antimicrobial and antifungal properties.

Tested as per DIN EN ISO 846 Method A for Fungal Growth
Tested as per DIN EN ISO 846 Method C for Bacterial Growth

Other Generics normally have antimicrobial and antifungal coatings which get washed off with time.
MICROBIAL GROWTH STUDY ON FIBRE GLASS

Fungal Growth

Bacterial Growth
MICROBIAL GROWTH STUDY ON FEFs & FIBRE GLASS

No Microbial Growth on FEFs

Very High Microbial Growth on Fiberglass
ENVIRONMENT FRIENDLY
ENVIRONMENT FRIENDLY INSULATION

Regulation of Hazardous Substances (ROHS) as below

- ROHS Compliant as per Directive 2011/65/EU Annexure – 2
- Zero ODP and GWP as per regulation EC 842/2006
- CFC / HCFC Free as per US EPA 5021A-2003

NBR based FEFS comply to these standards
SELECTION OF INSULATION THICKNESS

Weather Conditions

- Summer
- Monsoon
- Winters
SELECTION OF INSULATION THICKNESS

Surface Emissivity $\varepsilon \approx 0.93 \approx 0.28 \approx 0.05$
ISO 12241 – Standard for Thickness Calculation for Thermal Insulation

\[ C' = \frac{2\lambda}{h_{se}} \left( \frac{\theta_{im} - \theta_a}{\theta_{se} - \theta_a} \right)^{-1} \]

Relative Humidity (\(\phi\))

Ambient Temperature (\(\theta_a\))

Line Temperature (\(\theta_{im}\))

\(h_{se}\) – External Surface Coefficient of Heat Transfer

\(\left(\theta_{d} - \theta_a\right) = \quad \left(\theta_{se} - \theta_a\right) = -2.7\)

From Table 4 Page No. 20 of ISO 12241
SURFACE EMISSIVITY & CONDENSATION CONTROL

Surface Emissivity ε

- Armaflex® unpainted: ≈ 0.93
- With GI jacketing: ≈ 0.28
- With aluminum foil: ≈ 0.05
VALUES OF SURFACE COEFFICIENT

\[ \approx 9 \, \frac{W}{m^2 \cdot K} \]

\[ \approx 7 \, \frac{W}{m^2 \cdot K} \]

\[ \approx 5 \, \frac{W}{m^2 \cdot K} \]
VALUES OF SURFACE COEFFICIENT

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## EFFECT OF SURFACE COEFFICIENT ON INSULATION THICKNESS

<table>
<thead>
<tr>
<th>Cladding</th>
<th>Without Cladding or Insulation Painted</th>
<th>Steel Cladding</th>
<th>Aluminium Cladding</th>
<th>Static Area</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Surface Coefficient Value [W/m² K]</strong></td>
<td>9</td>
<td>7</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td><strong>Insulation Thickness s =</strong></td>
<td>s₀</td>
<td>1,5 * s₀</td>
<td>1,9 * s₀</td>
<td>3,0 * s₀</td>
</tr>
</tbody>
</table>
Stationary areas affecting the convective surface coefficient
Stagnant air increases the risk of condensation!

Lack of free air circulation (convection)!

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RECOMMENDED DISTANCES BETWEEN INSULATED OBJECTS AND ADJACENT STRUCTURE

DIN 4140 – Recommend minimum distance
DIN 4140 – Insulation work on industrial installations and building equipment – Execution of thermal and cold insulation
THANK YOU!

All data and technical information are based on results achieved under typical application conditions. It is the customer’s responsibility to verify if the product is suitable for the intended application. The responsibility for professional and correct installation and compliance with relevant building regulations lies with the customer. By ordering/receiving product you accept the Armacell General Terms and Conditions of Sale applicable in the region. Please request a copy if you have not received these.

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